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Patentanmeldung Nr. Patent application No. Demande de brevet n°

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PRIORITY DOCUMENT

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COMMUNICATIONS NETWORK

The present invention relates to a method of operating a packet network.

For many years, progress has been made towards specifying and building an integrated services communications network - i.e. a network that can carry both real-time traffic (e.g. voice, video) and non real-time traffic (e.g. e-mail). Two routing technologies have been put forward as suitable for the integrated services network. Both involve dividing a stream of digital data into packets for transmission over the network.

The first routing technology, packet forwarding, makes routing decisions for each packet based a destination address value carried in the packet. On receiving a packet, each switching element reads the destination address and forwards the packet from whichever one of its interfaces currently lies on the best route to that destination.

The second routing technology, label-switching, also requires a unique destination address to be provided to the network, but only once, at the beginning of the transmission. Once the destination address is provided to the network, a route to the destination address is set up. In setting up the route, each of the switching elements on the route stores data associating the interface which leads towards the source with an inbound label and the interface leading to the destination with an outbound label. After the route has been set up, the packets need only contain a label rather than a full destination address. This means that routing decisions for the individual packets can be made more quickly, although this is achieved at the expense of having to set up the label associations in the switches initially.

There are concerns that conventional switching elements using current packet forwarding technology might be unable to offer real-time transmission across the core of the network. To meet those concerns, a hybrid network technology, Multiprotocol Label-Switching (MPLS) has been proposed. MPLS enables the use of packet forwarding techniques in the periphery of a network, and label-switched techniques in

the core of the network. In many versions of the proposal, packets from different sources are assigned common labels before being forwarded across the core of the network.

According to a first aspect of the present invention, there is provided a method of operating a packet network comprising at least three nodes having respective external links to a subnetwork, said packets being constructed in accordance with a protocol that specifies a first set of predetermined locations in said packet to represent a source address, said method comprising:

operating each of a group of two or more of said nodes as a sender node to transmit one or more packets with a common group identifier in said first set of predetermined locations to one of said nodes which is operating as a recipient node, the transmission taking place via the sender node's external link to the subnetwork, the subnetwork and the recipient node's external link to said subnetwork; and

operating said packet network to process said packet in a manner dependent upon said common group identifier value in said first set of predetermined locations.

By assigning packets from different sources the same source address, and processing packets in a manner dependent on that address, the processing involved in selecting how the packet should be processed is reduced. Furthermore, the use of the source address field means that the size of the header is not increased. Hence, the efficiency of the communication (in terms of the size of the packet header in comparison to the size of its payload) is higher than would be achieved by the MPLS proposal or alternative proposals which add an extension header to the normal header of an Internet Protocol packet.

It is to be understood that the subnetwork may contain any number of switching elements interconnected via internal links (and not all the switching elements need be connected directly to one another). In particular, the subnetwork may comprise a single switching element.

In some embodiments, said packet network operating step comprises operating said subnetwork to forward said packet across said subnetwork in a manner dependent upon said common group identifier value in said first set of predetermined locations. In other embodiments, said packet network operating step comprises operating said recipient node in a manner dependent on said common group identifier in said first predetermined set of locations.

Preferably, said subnetwork operating step comprises operating said subnetwork to forward said packet over the external link leading to a recipient node selected in dependence upon said common group identifier value in said first set of predetermined locations. Routing the packet in dependence upon the common group identifier reduces the processing load placed on the subnetwork.

In preferred embodiments, said subnetwork includes, for each of said groups, stored data representing one or more routing trees associated with said group, said stored data comprising, for each routing tree, routing tree data identifying one of said external links as a root-bound external link in relation to said routing tree and a plurality of others of said external links as leaf-bound external links in relation to said routing tree; furthermore

packets having a common group identifier are forwarded over the external link defined as the root-bound external link in relation to the routing tree that corresponds to the group identifier value in said first set of predetermined locations in those packets; and

said protocol further defines a second set of predetermined locations to represent a destination address, said method further comprising:

operating one of said nodes to send one or more packets with said common group identifier in said second set of predetermined locations; and

operating said subnetwork, on receipt of a packet with said common group identifier in said second set of predetermined locations, to forward said packet over the leaf-bound external links associated with said routing tree for said group.

In this way the same data can be used both for routing packets from a selected node of a group to all the other nodes in a group and for routing from any one of the other nodes to the selected node. This results in further savings in the storage and processing burdens placed on the switching elements of the subnetwork. Note that this is achieved without any increase in the size of the packet header. Many multicast routing algorithms are known (e.g. Distance Vector Multicast Routing Protocol (DVMRP), Multicast extensions to Open Shortest Path First (MOSPF)), which can be used to generate the tree-defining data.

Further preferably, said packet forwarding step further comprises:

identifying those external links defined as leaf-bound external links in relation to the common group identifier value in said first set of predetermined locations; and

discarding said data block if it was not received over one of said leaf-bound external links.

This prevents the subnetwork forwarding a packet that falsely purports to have been sent by a member of the group.

In some embodiments, said subnetwork operating step comprises forwarding said packet across said subnetwork with a priority which is dependent on said common group identifier.

It will be seen by those skilled in the art that such embodiments provide an alternative to MPLS which proposes classifying packets entering a subnetwork into classes. Thereafter, all packets in a given class have a common label attached to them before being sent across the subnetwork. Within the subnetwork, those packets are scheduled in accordance with that label. It will be seen that the present invention achieves similar flexibility but does not result in an increase in the size of

the packet's header. Equivalent embodiments can provide group-dependent access lists, billing, and discard eligibility.

In preferred embodiments, said method further comprises the steps of:

operating said sending node to append a common group identifier value to a received data block before sending the packet thus formed to said recipient node, said common group identifier value being appended so as to be located in said first set of predetermined locations;

operating said recipient node to remove the common group identifier value before onward transmission of the data block.

Those skilled in the art will recognise that this embodiment involves 'tunnelling' a packet across the subnetwork. The tunnel thus formed is a multipoint-to-point tunnel. Tunnelling has a number of advantages. Firstly, the header information present in the packet before the common group identifier was appended can be re-used at the recipient node and in any network beyond that node. This may be used to provide a Virtual Private Network which uses a shared subnetwork. The original header information can be encrypted without affecting the operation of the subnetwork, thereby providing security for the communication between the sender and the recipient.

There now follows a description of specific embodiments of the present invention. These embodiments are described by way of example only with reference to the accompanying drawings, in which:

Figure 1 is an illustration of an internetwork operating in accordance with a first embodiment of the present invention to interconnect a number of Local Area Networks (LANs);

Figure 2 is a more detailed illustration of the internetwork of Figure 1;

Figure 3 is a flow-chart which shows how a router of the internetwork of Figure 2 operates in accordance with the first embodiment;

Figure 4 is a flow-chart which shows part of the operation of Figure 3 in more detail;

Figure 5A shows the format of a multicast IP packet sent by a computer on one of the LANs of Figure 1 to a computers on a selection of the other LANs;

Figure 5B shows the format of a multicast tunnel packet which is used in transmitting the packet of Figure 5A across the internetwork of Figure 2;

Figure 5C shows the format of a unicast IP packet sent by a computer on one of the LANs that receives the packet of Figure 5A back towards the LAN from which the packet of Figure 5A was sent;

Figure 5D shows the format of a many-to-one tunnel packet which is used in transmitting the packet of Figure 5C across the internetwork of Figure 2;

Figure 6A illustrates a routing tree for a one-to-many communication; and

Figure 6B illustrates a reversed version of the routing tree of Figure 6A for use in a many-to-one communication.

Figure 1 shows a shared internetwork S which interconnects six Local Area Networks (A to F). The six LANs (A to F) are connected to the shared internetwork S via six respective links (L1 to L6). Each LAN (A to F) comprises a number of computers connected to one another and to a gateway computer (G1 to G6) by a broadcast network (SL1 to SL6). Broadly, the shared internetwork S and Local Area Networks (A to F) operate in accordance with the IP protocol suite.

The computers A1 to F3, the gateway computers G1 to G6, and the routers that operate in the shared internetwork S (Figure 2: R1 to R6) are all types of nodes. In

accordance with the IP protocol suite, each interface between a node and a network link is associated with a unique 4-byte address. These 4-byte addresses are normally written as four decimal digits each of which represent the decimal value of a respective byte – for example the address associated with the interface between the computer A1 and the shared link SL1, might be 172.16.0.2. One possible configuration of IP addresses for the LANs of Figure 1 is given in Table 1 below:

Interface	IP address	Interface	IP address	Interface	IP address
A1 to SL1	172.16.0.1	B1 to SL2	172.17.0.1	C1 to SL3	172.18.0.1
A2 to SL1	172.16.0.2	B2 to SL2	172.17.0.2	C2 to SL3	172.18.0.2
A3 to SL1	172.16.0.3	B3 to SL2	172.17.0.3	C3 to SL3	172.18.0.3
G1 to SL1	172.16.0.4	G2 to SL2	172.17.0.4	G3 to SL3	172.18.0.4
G1 to L1	194.10.2.1	G2 to L2	194.10.3.1	G3 to L3	194.10.4.1
D1 to SL4	172.19.0.1	E1 to SL5	172.20.0.1	F1 to SL6	172.21.0.1
D2 to SL4	172.19.0.2	E2 to SL5	172.20.0.2	F2 to SL6	172.21.0.2
D3 to SL4	172.19.0.3	E3 to SL5	172.20.0.3	F3 to SL6	172.21.0.3
G4 to SL4	172.19.0.4	G5 to SL5	172.20.0.4	G6 to SL6	172.21.0.4
G4 to L4	194.10.6.1	G5 to L5	194.10.7.1	G6 to L6	194.10.9.1

Table 1

Those skilled in the art will recognise that the IP addresses assigned to the interfaces within the LANs (A to F) are private IP addresses. Packets having private IP addresses in their destination address field are not forwarded by routers in the public Internet (and, in the present example, are not forwarded across the shared internetwork S). In contrast, the addresses assigned to the interfaces between the gateway computers (G1 to G6) and the links (L1 to L6) leading to the shared internetwork are public IP addresses.

A more detailed diagram of the shared internetwork S is given in Figure 2. The internetwork S comprises six routers (R1 to R6), each of which has four physical communication ports. One of the communication ports of each router (R1 to R6)

receives a link (L1 to L6) to a respective one of the Local Area Networks (A to F). The other three communication ports receive links to respective other routers.

In more detail, a western central router R3 is directly connected via a central link CT to an eastern central router R4 and also to a north-western router R1 and south-western router R5 via a north-western link NW and south-western link SW respectively. Similarly the eastern central router R4 is directly connected to a north-eastern router R2 and a south-eastern router R6 via a north-eastern link NE and a south-eastern link SE respectively. A northern link N directly connects the north-eastern R1 and north-western R2 routers. An eastern link E directly connects the north-eastern R2 and south-eastern R6 routers. A western link W directly connects the north-western R1 and south-western R5 routers. Finally, a southern link S directly connects the south-western R5 and south-eastern R6 routers.

A possible configuration of the IP addresses for the interfaces between the internetwork nodes of the internetwork S and the links (L1 to L6, N, S, E, W, NE, SE, SW, NW, CT) is given in Table 2 below:

Interface	IP Address	Interface	IP Address
R1 to L1	194.10.1.2	R4 to L4	194.10.4.2
R1 to N	194.10.25.1	R4 to CT	194.10.12.2
R1 to NW	194.10.18.2	R4 to NE	194.10.11.1
R1 to W	194.10.15.2	R4 to SE	194.10.13.2
R2 to L2	194.10.2.2	R5 to L5	194.10.5.2
R2 to N	194.10.25.2	R5 to W	194.10.25.1
R2 to NE	194.10.11.2	R5 to SW	194.10.10.1
R2 to E	194.10.20.1	R5 to S	194.10.14.2
R3 to L3	194.10.3.2	R6 to L6	194.10.6.2
R3 to CT	194.10.12.1	R6 to E	194.10.20.2
R3 to NW	194.10.18.1	R6 to SE	194.10.13.1
R3 to SW	194.10.10.2	R6 to S	194.10.14.1

Table 2

Those skilled in the art will see that a Class C address has been assigned to each link (L1 to L6, N, S, E, W, NE, SE, SW, NW, CT). The links in this case are provided by Permanent Virtual Circuits set up in an Asynchronous Transfer Mode network that provides the shared internetwork S.

Each of the gateway computers (G1 to G6) and the routers (R1 to R6) operates in accordance with the Open Shortest Path First dynamic routing process (defined in Request For Comments (RFC) 1247 available from http://www.ietf.org/rfc/rfc1247.txt). Hence, each router (R1 to R6) generates a unicast routing table which indicates which of the router's interfaces provides the best route towards any reachable network. An example of such a routing table is given for the north-eastern router R2 in Table 3 below:

Destination Address	Best Output Interface
172.16.x.x [i.e. LAN A]	194.10.25.2
172.17.x.x [i.e. LAN B]	194.10.2.2
172.18.x.x [i.e. LAN C]	194.10.25.2
172.20.x.x [i.e. LAN D]	194.10.11.2
172.21.x.x [i.e. LAN E]	194.10.25.2
172.22.x.x [i.e. LAN F]	194.10.20.1

Table 3

Comparison with Table 1 will show how each of the entries on the left-hand side of Table 3 refers to one of the Local Area Networks (A to F). (Note that the information in square brackets is not actually stored in the router – it is included for the

convenience of the reader). The right-hand column of Table 3 indicates from which interface of the north-eastern router R2 a packet with a destination address listed in the left-hand column is to be sent.

Both the gateway computers (G1 to G6) and the routers (R1 to R6) operate in accordance with the Distance Vector Multicast Routing Protocol (defined in RFC 1075 available from http://www.ietf.org/rfc/rfc1075.txt). This results in each router (R1 to R6) further storing a multicast routing table which lists for each multicast group that is routed via that router:

for each computer in the multicast group that may act as a source node:

i) an indication of the interface through which packets addressed to that multicast group should be received; and

ii) an indication of the interface(s) through which multicast packets addressed to that multicast group are to be forwarded.

By way of example, assume the operator of the shared internetwork S provides a Virtual Private Network (VPN) that interconnects LANs A,B,D and F (this might be required where those LANs belong to the same organisation).

To provide the VPN the network operator firstly configures gateway computers G1, G2, G4 and G6 to be members of a multicast group associated with an IP address, say 230.10.10.1. Each of the elements of the shared internetwork S then operate in accordance with the DVMRP algorithm to generate entries relating to that multicast group in their multicast routing tables. The multicast routing table entry stored in the north-eastern router R2 might then appear as shown in Table 4 below:

Source Address	Destination Address	Best Input Interface	Output Interfaces
194.10.1.1	230.10.10.1	194.10.25.2	194.10.2.2

[i.e. G1]	[i.e. G1, G2, G4, & G6]		194.10.11.2 194.10.20.1
194.10.2.1 [i.e. G2]	230.10.10.1 [i.e. G1, G2, G4, & G6]	194.10.2.2	194.10.25.2 194.10.11.2 194.10.20.1
194.10.4.1 [i.e. G4]	230.10.10.1 [i.e. G1, G2, G4, & G6]	194.10.11.2	194.10.25.2 194.10.2.2 194.10.20.1
194.10.6.1 [i.e. G6]	230.10.10.1 [i.e. G1, G2, G4, & G6]	194.10.20.1	194.10.25.2 194.10.2.2 194.10.11.2

Table 4

The internetwork operator also configures each of the computers in the LANs A,B,D and F to address packets intended for one or more computers in all those LANs to multicast address 235.255.255.255.

The internetwork operator then places configuration data in the gateway computers G1, G2, G4 and G6. That configuration data associates destination addresses with tunnel data - the tunnel data at G1, for example, might be as follows:

Contents of Destination Address Field of packet from LAN A	Source Address of packet for onward transmission across shared internetwork S	Destination Address of packet for onward transmission across shared internetwork S
172.17.x.x [i.e. LAN B]	230.10.10.1	194.10.2.1
172.19.x.x [i.e. LAN D]	230.10.10.1	194.10.4.1
172.21.x.x [i.e. LAN F]	230.10.10.1	194.10.6.1
235.255.255.255	194.10.1.1	230.10.10.1

Table 5

In accordance with the first embodiment, a router (R1 to R6) is programmed to carry out the processes illustrated in Figure 3 on receiving an IP packet. It is to be understood that the flow-chart shows the processes only to the extent required to explain the present embodiment – processes that are carried out in conventional routers (such as header verification and error checking) are also carried out in the present embodiment but not discussed here.

Firstly, if the source address field of the received packet is in the range 224.0.0.0 to 239.255.255.255 (step 601) then a many-to-one forwarding process (step 602) is carried out (explained in more detail below in relation to Fig.4). If the source address is not in that range then, if the destination address contained within the received packet is in the range 0.0.0.0 to 223.255.255.255 (step 603) the router carries out conventional unicast forwarding (step 604) based on the destination address and its unicast routing table (Table 3). After unicast forwarding (step 604) the process ends (step 607). If the destination address contained within the received packet is instead in the range 224.0.0.0 to 239.255.255.255 (step 605) the router carries out conventional multicast forwarding (step 606) based on the destination address and its multicast routing table (Table 4). After multicast forwarding (step 606) the process ends (step 607). Also, if neither the source address nor the destination address is within the above ranges then the process ends (step 607).

As shown in Figure 4, the many-to-one forwarding (step 602) starts at step 701. Firstly, the multicast routing table is searched for an entry for a multicast group (i.e. the second column of Table 4 is searched) having the same address as the source address contained within the received packet (step 702). If a matching entry in the multicast routing table (Table 4) is not found, then the packet is discarded (step 710) before the many-to-one forwarding process ends (step 705).

If one or more entries corresponding to the multicast address contained within the source address field of the received packet are found in step 702 then a search is

carried out for an entry which also has a source address which corresponds to the destination address in the received packet (i.e. the first column of Table 4 is searched). Again, if no such entry is found, then the packet is discarded (step 710). If such an entry is found, then the received packet is forwarded (step 704) from the interface listed as the best input interface in that entry (i.e. the interface listed in the third column of Table 4). The many-to-one forwarding process then ends (step 705).

An example of the operation of first embodiment will now be given. In this example, the network has been configured as explained above and as illustrated in the accompanying diagrams and tables.

A user of the computer A1 instructs it to send an IP packet to computers B1, D1 and F1. Following its configuration, the computer A1 then sends a packet having a source address field which gives the IP address associated with the interface between A1 and the shared link SL1 (i.e. 172.16.0.1) and a destination address field 235.255.255.255. The packet is shown in Figure 5A.

This packet is received by the gateway computer G1 which notes that the destination address is one of those to be tunnelled (from Table 5) and therefore appends a header to the packet to create a tunnel packet. The tunnel packet uses the multicast address associated with the VPN and is illustrated in Figure 5B.

The gateway computer then sends the tunnel packet over link L1 to the shared internetwork S. Since the source address is not in the range 224.0.0.0 to 239.255.255.255 and the destination address is in the range 224.0.0.0 to 239.255.255.255, each of the routers carries out conventional multicast forwarding (step 606 in Figure 4). The shared internetwork thus multicasts the packet in a conventional manner to the recipient LANs B,D and F. A routing tree showing how the routers of the network would forward the packet is illustrated in Figure 6A. The header of the tunnel packet is then removed at each of the recipient LANs (B,D, and F) and the packets forwarded to the destination computers in a conventional manner.

To continue the example, a user of computer F3 on LAN F might instruct that computer to send a packet to computer A1 on LAN A. The packet sent by computer F3 onto LAN F has a conventional format as shown in Figure 5C.

On receipt of the packet at the gateway computer G1, the gateway computer looks up a Table equivalent to Table 5 above forms a tunnel packet containing the packet sent from computer F3. In accordance with that table, the value 230.10.10.1 is placed in the source address field of the tunnel packet, and the value 194.10.1.1 is placed in the destination address field of the tunnel packet. The tunnel packet is shown in Figure 5D.

Packets having a multicast address can be generated by running the FreeBSD operating system program (available from http://www.uk.freebsd.org) on each of the gateway computers G1 to G6. Other operating systems may also be used, but any part of the program that prevents the generation of packets having a source address in the range 224.0.0.0 to 239.255.255.255 will have to be removed.

Each of the routers receiving the many-to-one tunnel packet will carry out many-to-one forwarding (step 602) after finding that the source address of the many-to-one tunnel packet is in the range 224.0.0.0 to 239.255.255.255 (in step 601). The routes followed by many-to-one packets from LANs B,D, and F to LAN A are illustrated in Figure 6B. It will be seen that the routes are the reverse of those shown in Figure 6A and followed by multicast packets sent from LAN A.

It will be realised that both the tunnel packets mentioned above (Figure 5B and 5D) would be forwarded by router R2 using its multicast routing table (Table 4). It will be seen that both the many-to-one communication and the one-to-many communication use the same routing table entries. Hence, the number of routing entries that need be stored in the router R2 in order to forward packets from one of the members of the VPN to the others and from one of the members to another member, is reduced. Thus the amount of memory required at R2 is reduced as is the processing time required to search the routing table for the appropriate entry. Thus a packet

forwarding technology is provided that can alleviate concerns about the ability of the core of a network to handle real-time packets.

The new forwarding mode enables computers within a multicast group to send a packet to another member of the group anonymously. This is useful in relation to remote anonymous voting and the like.

Also, routers can be set up to respond to packets of the new type by forwarding packets received from any member of selected group more quickly than those received from other sources. The use of a group source address removes the requirement for the routers of the shared internetwork S from storing and maintaining lists of which computers are present in which groups. In general, the multicast source addresses of packets of the new type can be used to provide any differentiation of service that might be provided by say, the Forward Equivalence Class to be used in proposed Multiprotocol Label Switched networks.

In a preferred embodiment, the many-to-one forwarding process (Figure 5) includes a further input interface checking step immediately before the forwarding step 704. In the input interface checking step it is checked to see whether the packet has been received on one of the output interfaces (i.e. the fourth column of Table 4) associated with the entry found in step 703. If it was not received on one of those interfaces then the packet is discarded.

It will be seen how the preferred embodiment prevents computers on LANs which do not contain members of the multicast group from sending many-to-one packets which have the address of that multicast group in their source address field. In this way, computers which are not in the group are unable to take advantage of services intended only for group members. In order to control membership of the multicast group, methods such as those used in the Remote Authentication Dial In User Service (RADIUS) and the improvement thereof known as DIAMETER.

Although the above embodiment described the routers operating in accordance with the Distance Vector Multicast Routing Protocol (a protocol that builds so-called

'source-based trees'), it is to be understood that so-called 'shared tree' multicast routing protocols, such as Core-Based Tree might also be used.

As another variation, those skilled in the art will realise that the payload of the tunnel packet (which includes the header of the original packet) might be encrypted to provide security for the communication across the shared internetwork S.

In the above embodiment, all of the routers operated a many-to-one forwarding process. However, the embodiment is also of benefit in networks were only a subset of the routers operate such a process. That is because conventional routers will forward a packet based on its destination address, ignoring the source address field – i.e. they will not carry out steps 601 and 602 of Figure 4.

It will be realised that the present invention could be used in relation to a number of protocols other than IP version 4 mentioned above. Clearly, it could be used in relation to IP version 6.

Further embodiments of the present invention are similar to the above-described embodiments but have area edge routers in place of the gateway computers (G1 to G6). It will be realised that such an embodiment can provide differentiated services based on an address carried in an IP packet rather than on a label that would be attached to the packet in accordance with Multiprotocol Label Switching protocols.

Although, in the above embodiment, the internetwork S was configured to use 'tunnelling' to provide sites A,B,D & F with a Virtual Private Network, many of the advantages of the present invention would still pertain were the tunnelling feature to be removed. The multicast groups would then have hosts as members and it would be necessary to use public Internet addresses within the sites A to F. Furthermore, without tunnelling, the advantages would be achieved without increasing the size of the IP packet header.

All the above embodiments described the re-use of multicast routing tables, some embodiments of the present invention might not make use of the multicast routing

tables – for example, packets from A,B,D, & F could be provided with a Group E source address, the switching elements of the internetwork S operating to route the packets on the basis of that source address and a routing table that is provided at the switching elements by the network operator.

As a further alternative, routing could be carried out conventionally, but with scheduling processes being carried out in dependence on the Group E source address.

Any address value could be used in the source address field to represent the group. Group E source addresses are usefully employed since IP version 4 has not assigned any meaning to them.

CLAIMS

1. A method of operating a packet network comprising at least three nodes having respective external links to a subnetwork, said packets being constructed in accordance with a protocol that specifies a first set of predetermined locations in said packet to represent a source address, said method comprising:

operating each of a group of two or more of said nodes as a sender node to transmit one or more packets with a common group identifier in said first set of predetermined locations to one of said nodes which is operating as a recipient node, the transmission taking place via the sender node's external link to the subnetwork, the subnetwork and the recipient node's external link to said subnetwork; and

operating said packet network to process said packet in a manner dependent upon said common group identifier value in said first set of predetermined locations.

2. A method according to claim 1 wherein said packet network operating step comprises operating said subnetwork to forward said packet across said subnetwork in a manner dependent upon said common group identifier value in said first set of predetermined locations.

3. A method according to claim 2 in which said subnetwork operating step comprises operating said subnetwork to forward said packet over the external link leading to a recipient node selected in dependence upon said common group identifier value in said first set of predetermined locations.

4. A method according to claim 3 wherein:

said subnetwork includes, for each of said groups, stored data representing one or more routing trees associated with said group, said stored data comprising, for each routing tree, routing tree data identifying one of said external links as a root-bound external link in relation to said routing tree and a plurality of others of said external links as leaf-bound external links in relation to said routing tree;

said selected one of said external links comprises the external link defined as the root-bound external link in relation to the routing tree that corresponds to the group identifier value in said first set of predetermined locations; and

said protocol further defines a second set of predetermined locations to represent a destination address, said method further comprising:

operating one of said nodes to send one or more packets with said common group identifier in said second set of predetermined locations; and

operating said subnetwork, on receipt of a packet with said common group identifier in said second set of predetermined locations, to forward said packet over the leaf-bound external links associated with said routing tree for said group.

5. A method according to claim 4 wherein said packet forwarding step further comprises:
identifying those external links defined as leaf-bound external links in relation to the common group identifier value in said first set of predetermined locations; and
discarding said data block if it was not received over one of said leaf-bound external links.

6. A method according to claim 2 wherein said subnetwork operating step comprises forwarding said packet across said subnetwork with a priority which is dependent on said common group identifier.

7. A method according to claim 1 wherein said packet network operating step comprises operating said recipient node in a manner dependent on said common group identifier in said first predetermined set of locations.

8. A method according to claim 7 in which said recipient mode discards packets not having a predetermined common group identifier in said first predetermined set of locations.

9. A method according to claim 1 further comprising the steps of:

operating said sending node to append a common group identifier value to a received data block before sending the packet thus formed to said recipient node, said common group identifier value being appended so as to be located in said first set of predetermined locations;

operating said recipient node to remove the common group identifier value before onward transmission of the data block.

ABSTRACT

COMMUNICATIONS NETWORK

A method of operating a packet network is disclosed. There are concerns that conventional packet-forwarding devices will not be able to operate sufficiently quickly to transfer packets of a real-time communication across a network with an acceptably low level of delay. The method disclosed herein enables packets to be routed more quickly than has hitherto been possible by re-using multicast routing data for many-to-one communications. The method can also easily provide different quality of service levels to different types of packets and is especially useful in providing Virtual Private Networks across a shared internetwork such as the public Internet.

Figure (3)

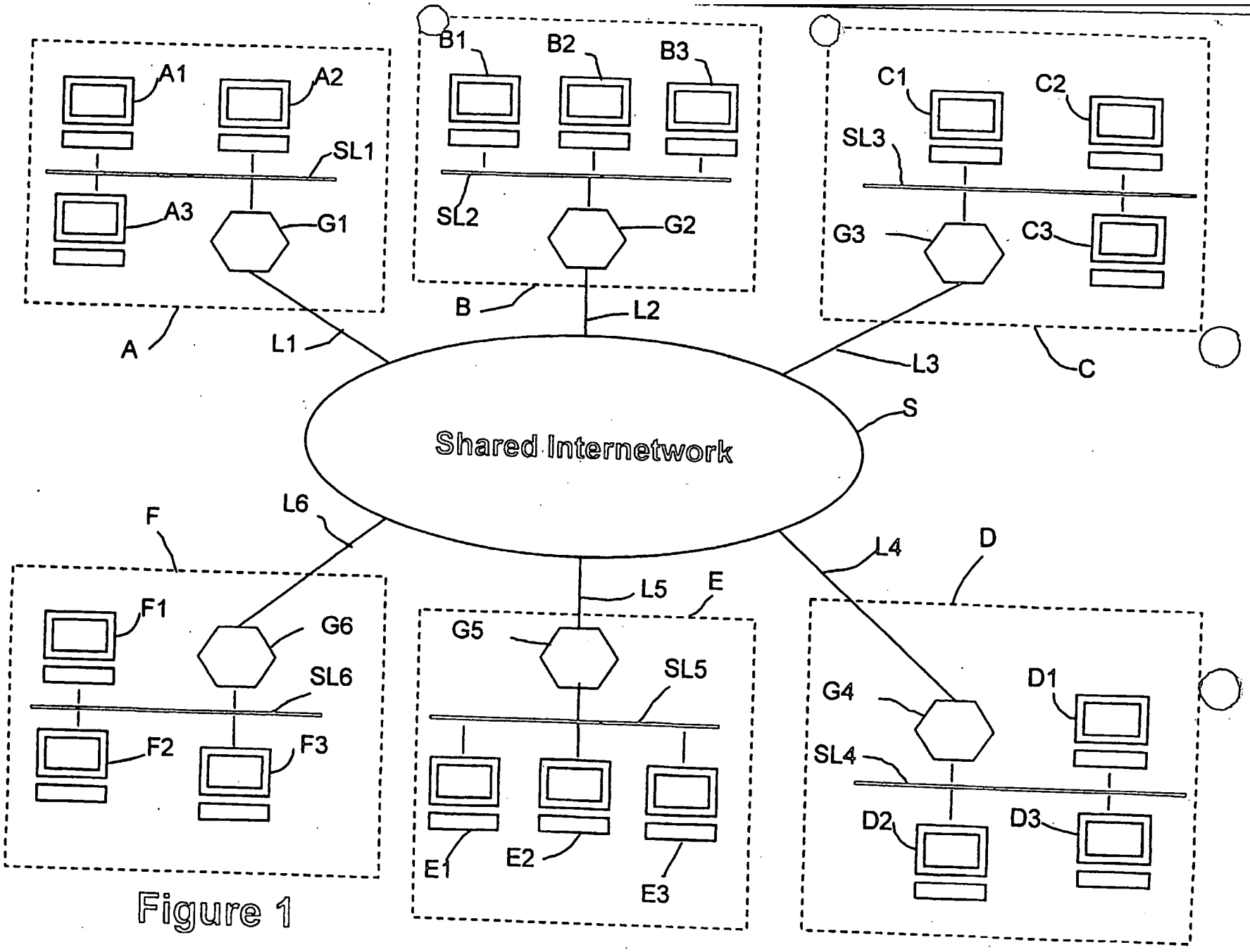
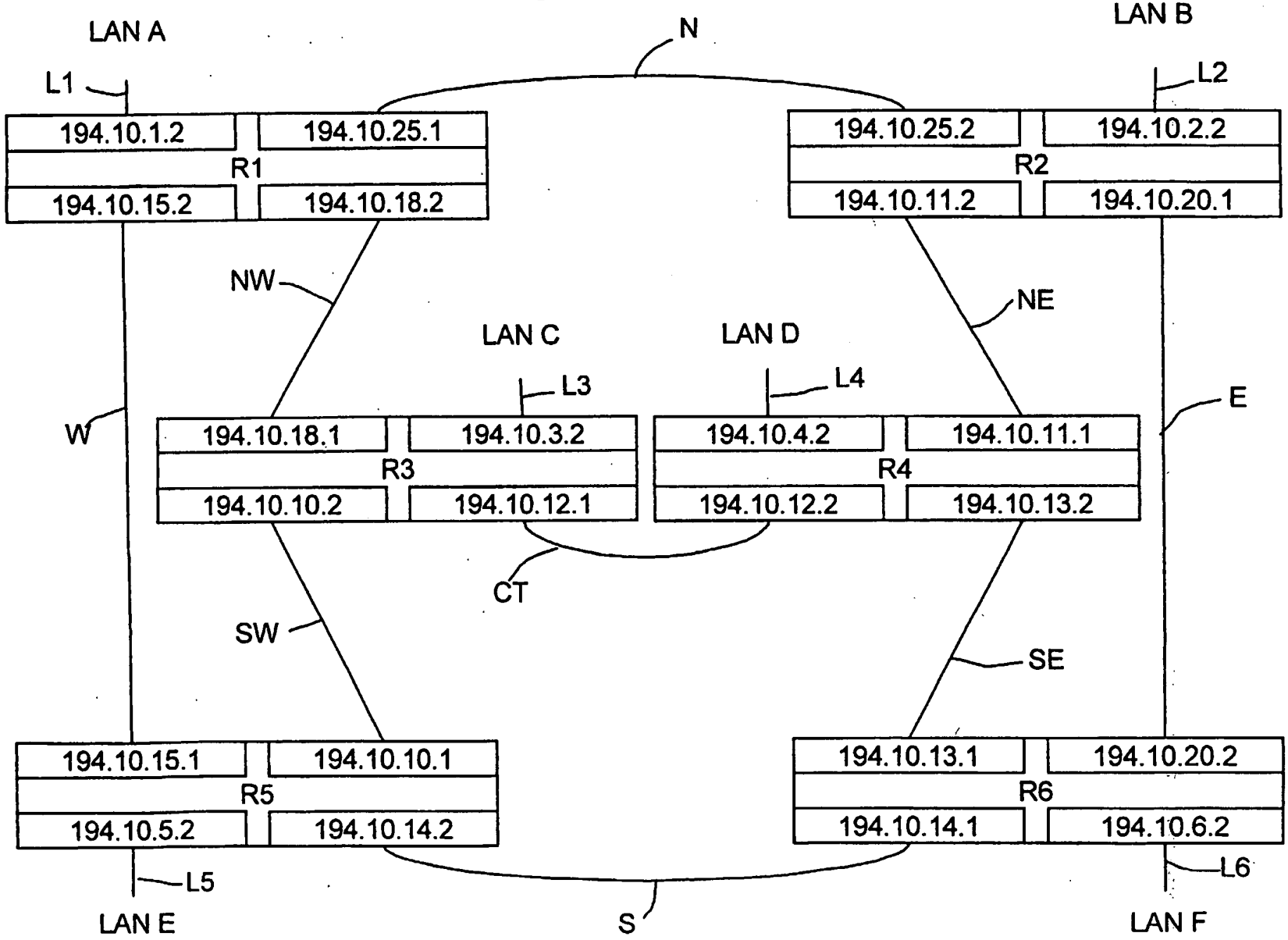


Figure 1

Figure 2



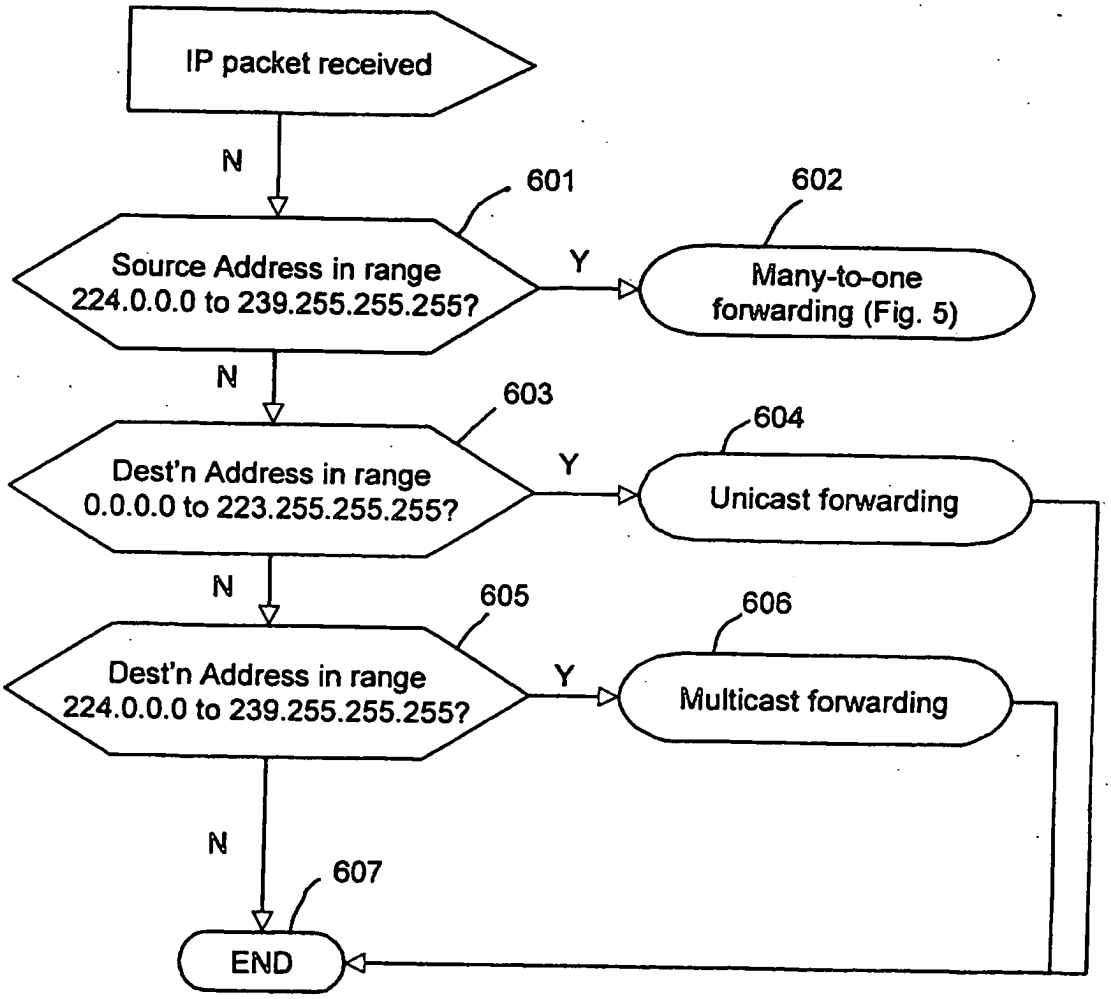

IP packet received
N
601
Source Address in range 224.0.0.0 to 239.255.255.255?
Y
602
Many-to-one forwarding (Fig. 5)
N
603
Dest'n Address in range 0.0.0.0 to 223.255.255.255?
Y
604
Unicast forwarding
N
605
Dest'n Address in range 224.0.0.0 to 239.255.255.255?
Y
606
Multicast forwarding
N
607
END

Figure 3

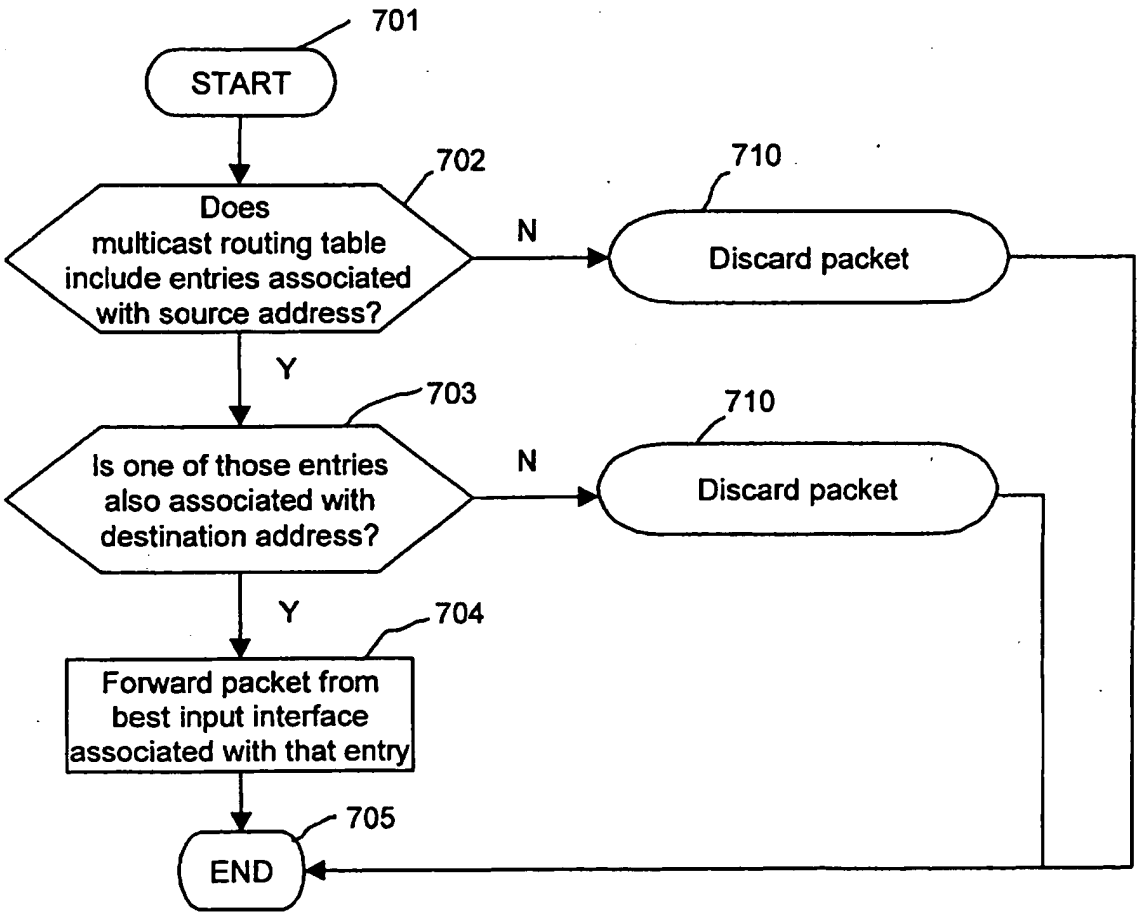

701
START
702
Does multicast routing table include entries associated with source address?
N
710
Discard packet
Y
703
Is one of those entries also associated with destination address?
N
710
Discard packet
Y
704
Forward packet from best input interface associated with that entry
705
END

Figure 4

Version		Type of Service	Total Length
Identification			
Time to Live		Protocol	Header Checksum
[Source Address =] 172.16.0.2			
[Destination Address =] 235.255.255.255			
Options			
Payload			

Figure 5A

Version		Type of Service	Total Length
Identification			
Time to Live		Protocol	Header Checksum
[Source Address =] 194.10.1.1			
[Destination Address =] 230.10.10.1			

Version		Type of Service	Total Length
Identification			
Time to Live		Protocol	Header Checksum
[Source Address =] 172.16.0.2			
[Destination Address =] 235.255.255.255			
Options			
Payload			

Figure 5B

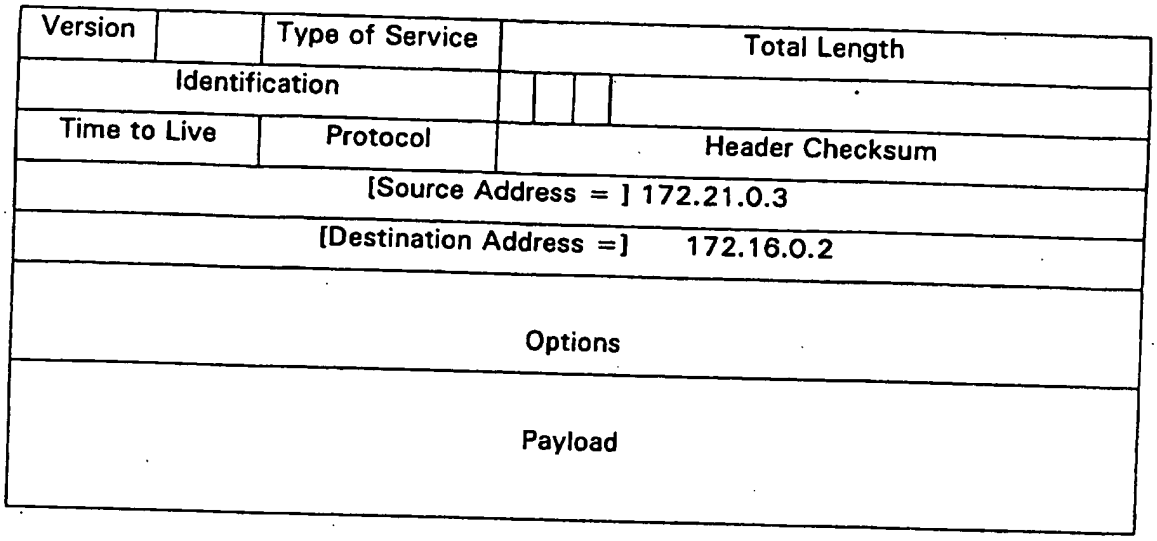

Version
Type of Service
Total Length
Identification
Time to Live
Protocol
Header Checksum
[Source Address =] 172.21.0.3
[Destination Address =] 172.16.0.2
Options
Payload

Figure 5C

Version		Type of Service	Total Length
Identification			
Time to Live		Protocol	Header Checksum
[Source Address =] 230.10.10.1			
[Destination Address =] 194.10.1.1			

Version		Type of Service	Total Length
Identification			
Time to Live		Protocol	Header Checksum
[Source Address =] 172.21.0.3			
[Destination Address =] 172.16.0.2			
Options			
Payload			

Figure 5D

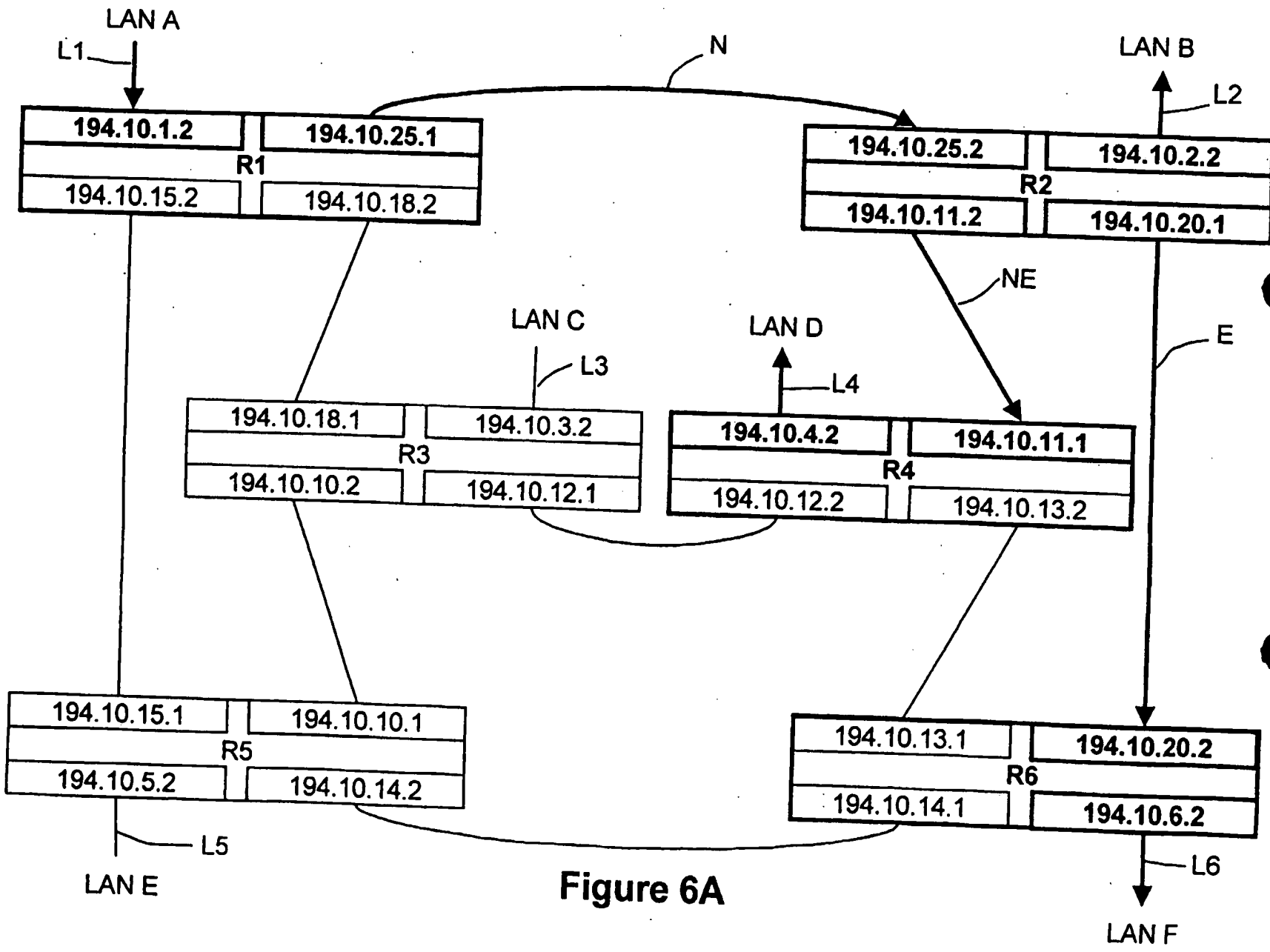


Figure 6A

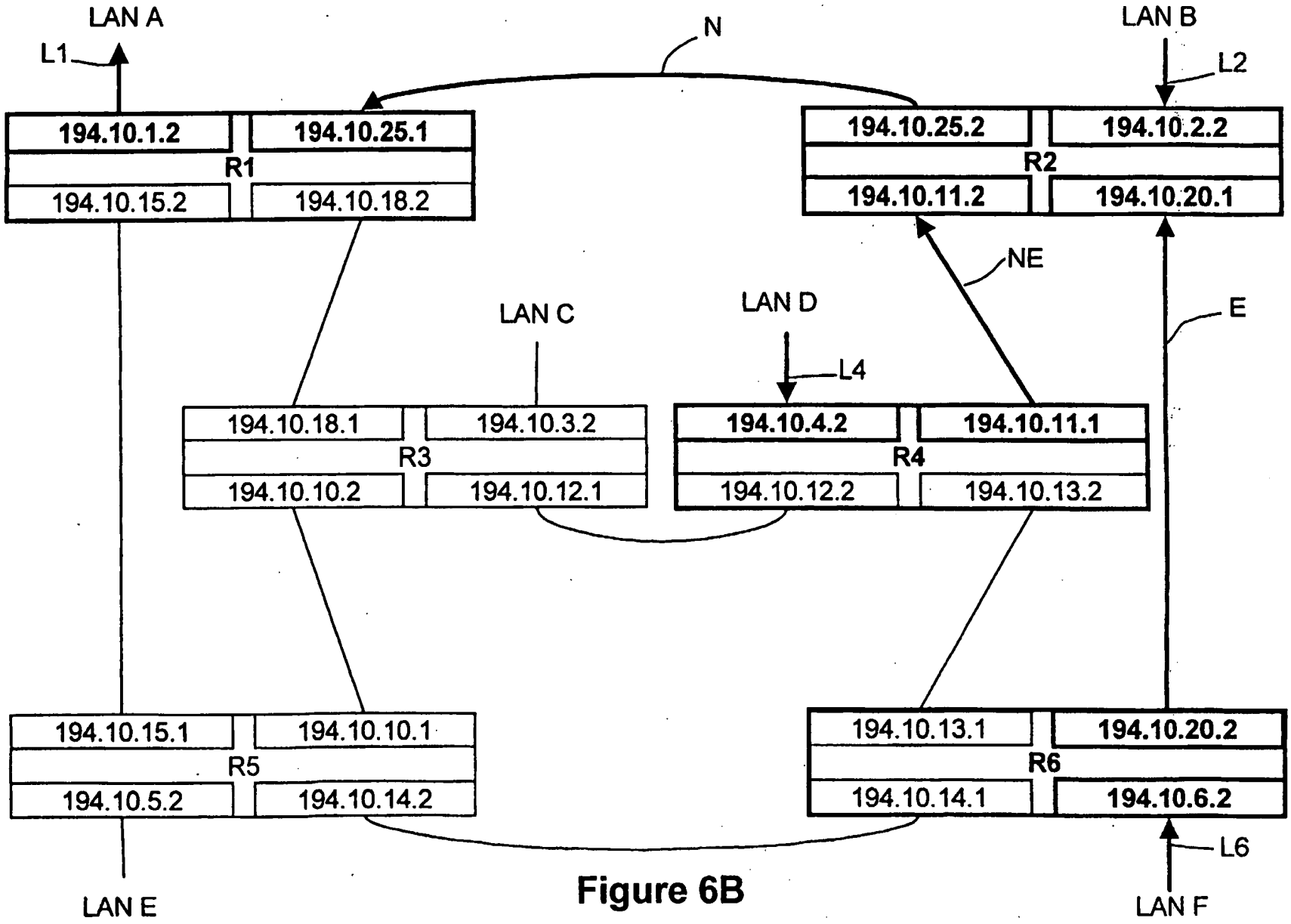


Figure 6B

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